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ABSTRACT

The study of alternative conceptions, or interpretations of ideas which differ significantly from the accepted scientific view at any time, has made rapid progress in the last few years. A detailed review of the field is not provided, rather achievements made and challenges for the future are noted. Areas addressed include: (1) the elucidation of alternative conceptions, discussing research methodology, need to produce diagnostic tests, and major content focus (mechanics and dynamics) in alternative conception studies; (2) conceptual development in physics; (3) approaches to developing conceptions in the classroom, indicating a key activity to be the generation of cognitive conflict in the individual student; (4) curriculum design; and (5) teacher education. It is noted that researchers in the alternative conceptions field have data which shows that some trainee physics teachers have similar conceptions to those of 12-year-olds. Therefore, it is suggested that the training of physics teachers should include ample time for the trainees to articulate, confront, and modify their own alternative conceptions. In so doing they will be subject to the same treatment that they will be encouraged to give to their students.
(Author/JN)

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ALTERNATIVE CONCEPTIONS : WHICH WAY NOW?

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An invited paper presented at the AAPT Winter Meeting 1983, New York.

Summary

The study of alternative conceptions, or interpretations of ideas which differ significantly from the accepted scientific view at any time, has made rapid progress in the last few years. In this paper I shall not attempt any detailed review of the field. Rather, I shall point to achievements already made and to challenges that can now be faced. My concluding thesis is that research and teaching practice within physics education must strive for a synthesis. This will unite researchers teachers and taught: all will be recognised as creators of knowledge.

The language of the research field

Every research field develops its own specialist vocabulary. The literature of contemporary physics is littered with unexplained references to 'quarks' 'gluons' 'pulsars' and the like. Likewise the papers produced by physics educators refer to 'misconceptions', 'alternative conceptions' 'alternative frameworks' and to 'children's science'. In the latter case these appear to refer to the same phenomenon. Yet this is not strictly true, for the words signal differing epistemological commitments.

Within the field of philosophy, a Realist is a person who believes that the world exists in an absolute sense such that absolutely true discoveries can be made by suitably trained observers. For a Realist, a concept will be the representation of generalities which have been observed among

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many particular perceptions. A concept will be formed by abstracting resemblances from among apparently dissimilar experiences. Where not all the relevant resemblances have been paid attention to, the outcome will be a 'misconception'. A misconception will be, axiomatically, untruthful and a prime candidate for authoritative correction. Knowledge is 'out there' and not the personal property of anybody. Commitment is only respected if it is to 'the truth'.

It seems very risky to discuss Relativism with the heirs of Einstein. Yet, and not only for the sake of symmetry, I must do so. A Relativist is a person who believes that the world presents a different appearance, dependent on the intellectual position from which it is viewed. For a Relativist, a favoured word is conception. A conception is a stable fund of expectation by which a person's reality can be organised. A conception is formed when a particular hypothesis about the environment is made and used. Negotiation between individuals can lead conceptions closer to the notion of a socially agreed concept. An 'alternative conception' is thus a conception which differs significantly from the socially agreed meaning. An 'alternative framework' suggests a more rigid and regular way of thinking. 'Children's Science' implies, on the other hand, a more strongly held relativistic view. Within a relativistic outlook, knowledge is created and owned by individuals. It is to be respected, being the outcome of honest endeavour. As we shall see later, this does not mean that alternative conceptions (which is the phrase I will use here) should not, cannot, and are not, modified.

These distinctions are not trivial. Where consciously and considerately used, they imply particular beliefs about the nature of knowledge and learning. As such, they govern what is to follow here. Indeed, unravelling personal epistemological positions in this field is the first and major

challenge which it presents to physics educators.

The elucidation of alternative conceptions

Although the epistemological position which it implies is not often directly addressed, the widely used Word Association Test eg Preece, 1976 seems realist in outlook. Large numbers of students are presented with a single stimulus word eg 'force' and required to write down words, that they associate with it, for a given short space of time. The data, which is thus cheap and easy to obtain, is subjected to mathematical analysis. The outcome is a structure said to represent the proximity of intellectual association seen between words by students. It is then compared with 'logically derived structures'. In common with Stewart (1979, 1980) I cannot see, using this method, why students should have made any particular association. As a consequence, I cannot easily see what to do with the outcome which is often so given as to indicate a personal characteristic of any given student.

The technique requiring the next highest level of inference on the part of the researcher is the multiple choice test. This often uses distractors derived from the misconceptions (sic) most commonly encountered in previous interviews eg Johnstone and Mughol (1978), Helm, (1978). A modification to the technique leaves a space for the student to explain the reasons for selecting a particualr answer eg Shipstone (1982). These two techniques have value in confirmatory survey work by researchers.

For researchers who see knowledge as a personal construction (see: Pope and Keen, (1981)), interviews must play a central role. These can be conducted individually without props to aid discussion eg Albert (1978), with cards or pictures to focus discussion eg Rodrigues, (1980),

Gilbert and Osborne (1980) or in conjunction with the manipulation of equipment after the manner of Piaget eg Trowbridge and McDermott (1980), van Zee, Evans, Greenberg, McDermott (1982). Moving away from the possibility of discussion between researcher and students, written explanations are produced by large groups of students, either in response to demonstrations eg Erickson (1980), or to diagrams eg Fredette and Lochhead (1980).

The most naturalistic setting for the study of conceptions must be the classroom, particularly where students are engaged in practical work. Methodically difficult though this is, interesting results have been obtained eg Séré (1982), Tasker (1981), Zylbersztajn and Gilbert (1981). A modification, which makes data collection easier, is to arrange for a small group of students to work separately eg Gilbert and Pope (1982).

This sketch of techniques used brings me to a second challenge facing physics educators. There is a pressing need to produce diagnostic tests for use by teachers in classrooms, and to make these widely available. The University of Surrey and B.P. Ltd. will be doing so during 1983 (see: Watts and Gilbert, 1983). An associated need is to further educate teachers in the observation and analysis of discourse in their own classrooms.

Using some of the papers quoted in this section as illustrations, it is possible to point to the particular areas of physics which have received attention by researchers into alternative conceptions. I have the overall impression that mechanics and dynamics have received most attention eg Trowbridge and McDermott (1980), Rodrigues (1980), Séré (1982), followed by heat and temperature eg Erickson (1980), Albert (1978) and

electricity and magnetism eg Fredette and Lochhead (1980), van Zee, Evans, Greenberg, McDermott (1982), Shipstone (1982). Little work has been done on light eg Stead and Osborne (1980) and apparently none on sound. This is particularly disappointing, since these phenomena are, for most people, of great cultural importance. The third challenge to physics educators is to broaden the base of their enquiries, perhaps moving their attentions towards physical phenomena of more general interest to the community.

Most enquiries conducted so far have been into conceptions held by high school (11 - 18 years) and University (18 - 23 years) students. I would expect the emphasis on high school work to continue, as an adjunct to attempts to increase the numbers of physics majors. Given that much early work in the University field was done in conjunction with remedial classes, and that higher education is currently, on a world-wide basis, becoming more elitist and specialised, I would expect interest here to wane somewhat. The exception may be in teacher training, a theme to which I shall return. Emphasis is shifting towards the primary (5 - 11 years) level, as shown by the promising work of the Science Education Research Unit at the University of Waikato, New Zealand. (see: Osborne, Symthe, Carr, Bidduph (1982)). Little, if anything, has been done with adults outside the formal education system, or with young people in vocational training. Here lies the fourth challenge.

Similarly, most studies have been within W.A.S.P. populations. Given their cultural connections, it is hardly surprising that studies throughout the world have shown similar results. Few cross-cultural studies have appeared eg Ross (1982), Klein (1982) and these have been appropriately cautious in their interpretations. Such ethnographic studies require

great tact. Similar arguments apply to studies of females and males anywhere. These constitute a fifth challenge.

Opponents of alternative conceptions would argue that in a class of thirty students there are bound to be thirty different conceptions associated with any one word and that these constantly change. Advocates of constructivist psychology eg Pope and Gilbert (1983) would agree on principle. However, mercifully for the sanity of researchers, teachers and students alike, most studies have shown less that ten distinguishable conceptions surrounding any one word (see: Watts, 1983) How sure can we be that such conceptions acually exist? There is no clear answer: I, for one, am convinced that the very act of enquiry causes an individual to revise a conception. At the very least, the outcomes of studies may represent the cultural history of individuals which is partially or wholly re-created in succeeding populations. Techniques for the analysis of discourse need to be further developed (see: Dumas-Carré and Delacôte (1981)). Convincing others that what a researcher sees in data is reasonable constitutes a sixth challenge to physics educators: what Watts (1982) calls 'authentication' continues to attract attention (see: Lecompte and Goetz (1982)).

Conceptual development in physics education

It seems amazing that Joe McKennon and Jack Renner could have asked the question 'are colleges concerned with intellectual development?' in 1971 (see: McKennon and Renner, 1971) to have it effectively echoed ten years later (Lin, 1982). In the meantime, however, much more has been learnt about the demands made by courses on students (Arons, 1979), and a body of work on alternative conceptions is now emerging.

Should physics education be concerned with intellectual development? The question is trite – the answer surely must be 'yes'. If intellectual development is to be promoted, what significance do alternative conceptions have? They can be modelled as interpretative frameworks which interact with what a teacher says or does to produce a range of outcomes from any learning experience provided for a class (Gilbert, Osborne, Fensham, (1982)). Only some of these are in a direction classically wanted by physics educators ie towards the socially accepted meaning of a word. This is supported by the few longitudinal studies (Engel (1982)) and cross-sectional studies (Nussbaum (1979)). The hope of moving students along rapidly from a 'novice' understanding to an 'expert' understanding seems perhaps rather ambitious (see: Chi, Feltovich, Glaser, (1980); Champagne, Klopfer, Desena, Squires (1981)).

What we lack is a useful model of how children's alternative conceptions change. Is it in a step-wise manner, with periods of quiescency interspersed with sudden changes? Is it smooth, in an evolutionary manner suggested by the work of Toulmin (1972)? Can it be modelled using catastrophy theory? (see: Gilbert and Watts, 1983). A seventh and massive, challenge to physics educators is to produce a viable model of conceptual change. It will only be then that studies, and classroom strategies, can move on from essentially ad hoc approaches.

Developing conceptions in the classroom

When practising teachers hear about alternative conceptions, their first question is often 'what can I do about it, given a chronic lack of resources of time and equipment?'. The answer is quite a lot. Approaches to concept development which presume no poor knowledge in students seem to have little obvious relevance here. (Tennyson and Park, 1980). Approaches

which emphasise the restructuring of knowledge (Rumelhart and Norman, 1978) and the conditions under which change occurs (Strike and Posner (1982); Hewson (1981)) seem potentially helpful.

The key activity seems to be the generation of cognitive conflict in the individual student (Rowell and Dawson, (1979); Stavy and Berkovitz (1980); Bryant (1982)). At the present time the best developed classroom strategies are due to Nussbaum and Novick (1981). They consist of: setting the class a problem, often by demonstrating a phenomenon; requiring students to produce their own explanations; encouraging group discussion to eliminate weak models; a plenary discussion and additional practical work to close on the 'approved' explanation. Whilst this approach does seem fruitful, the mechanisms at work have yet to be elucidated and there is some doubt as to the scope of its applicability (Keil (1981)). This is the eighth challenge.

Challenges nine to twelve can be dealt with summarily, if only because relatively little has been written which is of especial relevance to physics educators. Number nine is the need to find practical strategies for the improvement of classroom discourse. This is particularly true in regard of the use of metaphor (Pope and Gilbert, 1983) because of its importance as a cognitive bridge between established and novel knowledge. The need to more fully investigate the roles of practical work in the learning of physics is number ten. Whilst quite a lot of practical work is done, at least in the U.K. (Beatty and Woolnough (1982)) there is a great deal of ambiguity about its purposes. Valuable though it may be for promoting cognitive conflict (Rowell and Dawson, 1981), the high cost makes it extremely vulnerable in the current season of resource famine. The dominence of norm referenced assessment, or 'grading on the

curve', has to give way to criterion referenced methods, where marks are given for particular achievements, if the cultural value of alternative conceptions is to be recognized. Challenge number eleven is to develop practical schemes for this (see: Kellington and Mitchell (1979); Friel and Johnstone (1978)). The last in this series concerns the design of textbooks to start their treatments of topics from the several points indicated by various alternative conceptions. The current situation is unsatisfactory, as Mann (1981) puts it

> "the time has come to put the traditional textbooks out of their misery and to start teaching students about physics"

In particular there is a need for specialist monographs for teachers which deal with single concepts with rigor and in depth (see: Paolini (1982); Gardner (1981)).

Curriculum Design

Traditionally curriculum design has consisted of deciding on aims and objectives, identifying suitable content, choosing teaching methods, selecting assessment techniques and stirring with as many resources as could be acquired, perhaps in the light of a favoured psychology of learning. The one element usually overtly (if not covertly) missing is any consideration of philosophy of science. This seems a strange omission, particularly as one major aim for physics education has been to 'develop, if not make, apprentice physicists'. One would expect that philosophy of science education would be evolved in the light of philosophy of science.

The omission may, in part, have been due to a lack of a consensus on which philosophy of science most closely reflects the actual practice of

science. In a series of essays Swift, Gilbert, Pope, Zylbersztajn and Watts (1982) have considered the potential impact of five major philosophers of science (Bacon, Popper, Kuhn, Lakatos, Feyerabend) on the practice of school science education. Space here does not permit a reworking of these interesting themes. I personally found Feyerabend's approach to be a breath of fresh air, for it denies the existence of any coherant and codifiable method for the conduct of science. Its implications for the conduct of science education emphasises the encouragement of imaginative thinking and the recognition of science as the outcome of human creativity, an approach which has found support elsewhere. (Perkinson (1970); Swartz (1982)). If alternative conceptions are to be viewed as the outcomes of scientist-like activity on the part of individuals (see: Pope and Keen (1981)), then their development will involve the deliberate consideration, by teachers and taught, of what 'being a scientist' is (or is not). This view might lead curriculum design on from its current implicit reliance largely on Baconian empirical inductivism (Swift, (1982)). There is a pressing need for enquiries (Challenge No. 13) into perceptions of the processes of science by teachers and taught (Posner and Hoagland (1981)).

In the meantime, imaginative attempts are being made to develop instructional systems in the light of recent psychological advances in general, and alternative conceptions in particular eg Shuell (1982); Champagne, Klopfer, Gunstone (1982), Hewson and Posner (1981). There is obviously room for major contributions by many other practising teachers - Challenge No. 14. In doing so, they will need to confront the basic philosophic question: what ought they to do? For those students who show themselves practically capable of doing so, the traditional route of development is towards 'scientists science'. For

those who cannot, or who reasonably do not wish to, develop in that direction, instruction might be designed to help them appreciate the strengths and limitations of their own conceptions, and come to an awareness of a different set of beliefs held by scientists. For others, a range of new experiences might be provided without the intention of promoting change. These differing approaches will have to be reconciled with general notions of 'equality of opportunity' - a massive expansion of adult education (science literacy) classes will be called for.

Teacher Education

Many researchers in the alternative conceptions field have data which shows that some trainee physics teachers have similar conceptions to those of twelve-year-olds. An extended course of physics has had little effect on the understanding of basic ideas in the field. This dismal fact is usually discussed sympathetically - the overloading of syllabii is so great that Einstein is introduced to Aristotelians who would find Newton revolutionary. The training of physics teachers should, in my opinion, include ample time for the trainees to articulate, confront and modify their own alternative conceptions. In so doing, they will be subject to the same treatment that they will be encouraged to give to their students: the medium and the message will have coalesced.

Trainees will need to know something of the patterns of alternative conceptions likely to be found amongst their students. To this will be added the development of the skills and knowledge which will be identified when my 14 challenges have been met. The implications are for a gradual and systematic overhaul of teacher education. If my readers agree, I leave it to them to consider criteri on which existing material might be ejected from an already - overcrowded syllabus. In my opinion, one

cardinal rule should be followed: knowledge, skills and attitudes to be developed should always emphasise that knowledge is a human creation manufactured in an infinite variety of ways, a personal possession to be developed, modified and abandoned.

Concluding Remarks

Nobody seems to know where the alternative conceptions field started up. My own opinion is that the late Dennis Driscoll of Canberra College of Advanced Education had a hand in it by elicidating misconceptions (sic) of chemical equilibrium during the early 1970's. To this day, new (and particularly isolated) research workers often start by talking about misconceptions before (usually) changing their terminology into a more relativistic mould.

Equally problematic is why it started up. Perhaps the progressive disillusion with the weaknesses of Piagetian stage theory (Brown and Desforges (1979)) was a factor. Certainly the gradual world-wide decline in interest in the study of physics as a subject in its own right might have contributed. In any event, it is gradually coalescing into a recognisable research and development movement (Gilbert and Swift (1982)) concerned with evolving science for all.

The question 'which way now?' has been answered by 14 challenges which amount to 'all ways now'. If a relativistic approach is, even partially, adopted then the alternative conception movement will signal a more common purpose for students, teachers and researchers. All will simultaneously become more student-like, more teacher-like and more researcher-like. A greater commonality of purpose, however far this is possible and desirable, can only be for the benefit of physics education

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SOME CHALLENGES PRESENTED BY THE ALTERNATIVE CONCEPTIONS MOVEMENT

Students, teachers and researchers should:

- identify their beliefs about the nature of knowledge
- develop diagnostic tests for use in classrooms
- broaden the range of themes researched into
- enquire amongst the non-educationally-captive population
- undertake cross-cultural studies
- develop procedures for authenticating results
- produce models of conceptual change
- describe the nature of cognitive conflict
- devise ways of improving classroom discourse
- establish roles for practical work
- develop criterion referenced testing procedures
- consider the structure and function of textbooks
- enquire into philosophies of science in the classroom
- work together on curriculum design

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